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Issued January 23, 1909.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—Circular No. 23.
B. T. GALLOWAY, Chief of Bureau.

POTATO DISEASES IN SAN JOAQUIN COUNTY, CALIFORNIA.

BY

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1909

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[Cir. 23]

POTATO DISEASES IN SAN JOAQUIN COUNTY, CALIFORNIA.

INTRODUCTION.

During recent years an important center for vegetable growing has developed in San Joaquin County, Cal., through the reclamation of the tule or peat lands in the deltas of the San Joaquin and Sacramento rivers. The potato is the principal crop, about 25,000 acres being planted. It is also one of the most profitable crops under normal conditions.

The agriculture of the region is remarkable for the large areas under one management, reaching several thousand acres in some cases. Most of the land is cultivated by renters who are not permanent residents. The tule lands lie for the most part near or below the high-tide level of the river. They were originally partially overflowed and covered with a dense growth of marsh plants, but are now reclaimed by the construction of levees along the river bank and the installation of pumping plants to remove the water. The soil consists of a deposit of several feet of the peat formation locally known as tule, which contains a large amount of organic matter only partially decomposed, formed by the decay of rushes, sedges, and other plants native to those warm valley marshes. Under cultivation and irrigation this soil works down to a very fine and uniform texture, but is at first quite rough and lumpy.

Since the rainfall is only about 15 inches, irrigation is essential for crop production on these peat soils. Water for this purpose is admitted from the river and distributed over the level fields in small ditches 60 to 80 feet apart. The water passes quickly through the loose peat soil until the water table is raised nearly to the surface, making in effect a system of subirrigation. As the land lies too low for water to run off, a system of drainage is essential. This is accomplished by means of large pumps which discharge the water into the river.

Potatoes are planted in March and April as a rule, and are harvested as the market requires them, from the last of September through October and November. While several other crops are grown on the peat lands, including barley, beans, onions, and asparagus, no fixed system of rotation of crops is practiced. It is customary to plant potatoes when the lands are first cleared, and usually for two or three years, after which the diminished yield and inferior quality of the potato crop cause the land to be put into barley or beans. After an interval of one or more years potatoes are again planted, since, as this crop returns the largest profits, the growers desire to plant it as continuously as possible. This, of course, is not good agricultural practice.

It has been found impossible to grow potatoes continuously on these peat lands in spite of their apparently inexhaustible fertility. The first crops grown after the land is reclaimed are phenomenally large, 300 to 800 bushels per acre, and of good appearance. After the first or second year, however, the yield diminishes rapidly and the tubers become rough and scabby to such an extent as to wipe out all profits.

In the summer of 1908 the Bureau of Plant Industry was called on to determine the causes of this condition. An inspection of the fields brought out the fact that several plant diseases appear to constitute the principal limiting factors in this industry. A diagnosis of the troubles, with some suggestions for their treatment, is given herewith. Entirely adequate measures for their control are not yet available, but may perhaps be worked out by further experimentation.

POTATO WILT.

THE CAUSE OF "POTATO-SICK" LANDS.

The principal cause of the marked decrease in the yield of old potato land is the presence of a fungous disease, the wilt, or dry-rot (*Fusarium oxysporum* Schlecht.). The connection of such a parasite with the troubles experienced had not been realized by the growers, nor had the fungus been reported from the Pacific coast, but a careful study of it had been made in the east by Dr. Erwin F. Smith and Mr. Deane B. Swingle,[a] of this Bureau, who worked out quite fully the nature and cause of the disease and the character and life history of the fungus causing it. The wilt is apparently not as prevalent or as injurious in the Eastern States as on the Pacific coast, and but little work has yet been done on methods for controlling it.

DESCRIPTION OF THE WILT.

The effects of the wilt as observed in California are exactly as described by Smith and Swingle from plants grown in the District of Columbia. The disease first becomes noticeable when the plants are about a foot high, though in mild cases it may not appear till near maturity. The leaves have a lighter green color and slowly assume a dull, unhealthy appearance, with a rolling or curling of the margins. The progress of the disease is slow. Gradually the tops wither or fall over and the general effect is of premature ripening.

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[a] Bul. 55, Bureau of Plant Industry, "The Dry-Rot of Potatoes Due to Fusarium Oxysporum." 1904.

The diseased plants are easily pulled up; the roots are partly dead and brittle. The wilt fungus frequently appears on them as a white or pink mold, and when the underground portion of the stem is cut across a pronounced brown discoloration is visible. This brown stain is also found in the branches leading to the tubers, and a thin slice across the stem end of the tuber will often reveal its presence there as well.

Examination of thin sections of these browned stems under the microscope shows the fungus to be abundant in the water-carrying vessels of both underground stems and roots; where it appears as delicate, colorless threads, bearing tiny elliptical spores.

The yield from diseased hills is greatly diminished, particularly if the attack begins early in the season.

THE DRY-ROT OF THE TUBERS.

When the potatoes are dug there is rarely any external evidence of the disease on them. The major portion of the crop produced from wilted plants is nevertheless infected, the fungus having entered the tubers through their stems. If these potatoes are stored in a cold place, but little change occurs, as the fungus requires warmth for its development. When infected potatoes are kept in a heated room or left outdoors in a warm climate, a dry-rot soon develops.

As the fungus spreads through the potato the tuber shrivels, beginning at the stem end; the inside becomes brown and light in weight. Occasionally bacteria cause a secondary soft-rot, which proceeds more rapidly. An early form of this Fusarium dry end-rot is frequently met with shortly after digging, and potatoes thus affected are known to buyers as "jelly ends."

The presence of the dry-rot fungus can be detected in otherwise normal tubers only by making a thin slice across the stem end and searching for the brown discoloration. Such potatoes are not desirable for seed, but are not objectionable for cooking, provided they are consumed promptly or kept in cold storage.

RELATIONSHIP OF POTATO WILT TO SIMILAR DISEASES IN OTHER CROPS.

The potato wilt belongs to a group of diseases which play a prominent rôle in American agriculture. It is related to the wilt diseases of cotton, watermelon, cowpea, tomato, etc., which are common in the warmer sections of our country. The watermelon growers of San Joaquin County have had experiences similar to those of the potato growers. Their soils become "melon sick" after a few crops, the reason being the presence of the watermelon wilt fungus. The cotton and cowpea wilts of the Southern States behave in the same way. The Bureau of Plant Industry has, however, succeeded in combating them by developing wilt-resistant varieties that will grow on infected land. The Fusarium wilt of the tomato, prevalent in Florida and the Gulf States and in California and the Southwest, is probably even more closely related to the potato wilt.

SOIL FERTILITY NOT A FACTOR AFFECTING WILT.

The current explanation given by the growers for the decreased productiveness of old potato fields is that the potato crop has exhausted some particular element of plant food that it requires. There is no evidence, scientific or otherwise, to support this view. The peat lands are extremely fertile. Other crops planted after potatoes produce a full harvest. If any substances injurious to the potato were given off during its growth they would be neutralized by the superabundant organic matter present. Fertilizers applied to peat soils subject to the potato disease appear to have no effect. Finally, there is enough of this Fusarium wilt present to fully explain the lessened yields.

MANNER OF INFECTION AND SPREAD.

The wilt fungus enters the plant from the soil through the roots or underground stems. The tubers are infected through their stem ends or, rarely, through wounds.

How the fungus spreads from field to field is not fully demonstrated. It may be present in nature in some of these alluvial soils. It is noteworthy that soils of this type appear to be predisposed to infection. One of the principal means by which the wilt has been disseminated is clearly by the use of infected seed tubers. Not only is the local crop usually infected, but the same wilt is very prevalent in Oregon, whence most of the outside seed potatoes are obtained. Unfortunately, nearly all of the area under discussion has become infected. The problem for the future is not so much to check the spread of the disease as to control it where it occurs.

REMEDIAL MEASURES FOR WILT.

Diseases of the type of potato wilt are very difficult to control. The source of infection and the seat of the disease are underground; hence, spraying with fungicides would be ineffective. There is no likelihood that applications of fungicides to the soil would do any good, and Dr. Erwin F. Smith's experiments indicated that fertilizers had little or no restrictive effect on the disease.

ROTATION OF CROPS.

Experience has shown that the amount of infection diminishes when barley, beans, or other crops are grown. Potatoes planted after a short rotation show much less wilt, and while it is doubtful whether the disease can be gotten rid of entirely by any rotation that would be adopted by San Joaquin County growers, there is no question that rotation of crops will continue to be the principal preventive measure in this district until resistant varieties are developed. The most profitable length of rotation remains to be determined by further trials. Comparisons should be made of plots or fields that have been one, two, three, and four years in other crops than potatoes.

The relative value of the various crops in reducing the amount of potato wilt is unknown. The fungus is thought not to attack barley, beans, or other vegetables likely to be grown, with the possible exception of tomatoes, which would better be avoided. For the present, the principal consideration in selecting rotation crops will be their profitableness. This subject will be further discussed later in this circular.

WILT-RESISTANT VARIETIES OF POTATOES.

Dr. Erwin F. Smith advises that an effort be made to secure resistant strains, as he saw indications that some plants in the fields he studied were resistant. We have as yet no information concerning the relative resistance of American varieties, but such tests should be made at once, as well as attempts to produce better strains by hill selection and to breed new resistant seedlings. The fact that wilt-resistant varieties of cotton, cowpeas, and watermelons have been secured is an encouragement to enter the more difficult field of potato breeding.

SANITARY MEASURES.

Under present conditions the entire quantity of potato tops are left in the field, together with thousands of bushels of small and scabby potatoes unfit for marketing. All this refuse affords a breeding place for the wilt fungus. In consideration of the fact that the next move of the farmer must be to rotate crops to get rid of fungous infection, it would seem a logical precaution to carry off and destroy all vines and culls at once after digging. It must be admitted that there is as yet no evidence that this would be profitable, but the experiment should be undertaken.

A HEALTHY SEED SUPPLY.

The indications are that most of the potatoes in the district referred to are infected with Fusarium when planted. It is reasonable to suppose that better results would follow the use of healthy seed, and trials should be made at once to demonstrate this. Search should also be made for a satisfactory source of disease-free seed. The Puget Sound country appears to be the most promising in this respect. If local seed or Oregon seed is to be used, an effort should be made to restrict the development of the Fusarium by storing the seed potatoes in a well-ventilated house at a temperature of about 40° F.

POTATO SCAB.

Scab, a disease causing rough, pitted tubers, is very prevalent in California, where it is considered the most serious enemy of the crop, since its injuries are brought conspicuously to the attention of the grower by the enforced rejection of the scabby potatoes.

LOSSES FROM SCAB.

The loss from scab is very heavy. There is, in the first place, a reduction of yield due to the attack of this fungus on the underground portions of the plant, and, secondly, a depreciation in quality. The very scabby potatoes are not marketable, and usually have to be left in the field, as there is at present no starch or alcohol factory to utilize the culls. The writer has roughly estimated that from 5 to 75 per cent of the crops are rejected on account of scab, the lowest amounts being found on land planted for the first time in potatoes, and the highest on old land. Possibly 25 per cent is an average loss on land previously planted to potatoes. As the annual production of potatoes in San Joaquin County is more than 2,500,000 sacks, the loss from this disease might easily amount to over $300,000 per annum.

Two forms of scab appear to occur in this area. The indications are that the principal injury is caused by the same disease that occurs in the Eastern States, which has been shown to be due to a fungus, *Oospora scabies*. There is at present, however, a good deal of another fungus, Rhizoctonia, to which has been attributed a stem-blight prevalent in heavy western soils and a surface cracking or russeting of the tubers.

CAUSE OF SCAB.

The cause of the scab is a minute parasitic fungus. The disease does not develop except where this fungus is present. The amount of scab is, however, greatly influenced by certain soil conditions. The principal factor appears to be the acidity or alkalinity of the land. The scab develops most freely in an alkaline soil and is greatly retarded by acidity. In this respect the San Joaquin County soils are extremely favorable to its development. The amount of moisture also exerts an influence on the disease; it appears to be worse in wet seasons and in wet soils. It is the experience of growers that it varies greatly in different seasons, yet, nevertheless, it can be prevented by excluding the germs of the disease.

PREVENTIVE MEASURES FOR SCAB.

(1) *Clean seed.*—The most frequent source of infection lies in the seed planted, and the experience of eastern growers has been that by disinfecting the seed and by planting in land free from scab a clean crop may be produced. It is therefore of the greatest importance that those California growers who have land not already infected by this disease should seek to keep it healthy by allowing nothing but disinfected seed to be planted.

In the majority of cases, however, it is necessary to deal with land that has already been infected by the cultivation of one or more potato crops. The disease has already been introduced; the problem is, how to control it. It goes without saying that additional reinfection should be avoided by disinfecting all the seed planted, in accordance with directions given later in this publication. Additional means to be adopted comprise:

(2) *Rotation of crops.*—Scab tends to diminish when land is planted in crops which do not harbor the parasite. Other root crops, however, such as sugar beets, turnips, etc., must be avoided. The length of time required to free land from scab varies in different sections, but, as a rule, a period of three years will very greatly reduce the amount of disease, though it may not be entirely exterminated after five, or even ten, years.

The principal point to be kept in mind in choosing rotation crops is to increase the amount of organic acids in the soil by plowing under green crops, such as rye, clover, vetch, etc., which by their decay tend to produce an acid reaction in the soil. It is possible that the soil can be further favorably modified by the use of fertilizers, such as acid phosphate, muriate of potash, land plaster, etc., which leave an acid residue. It seems at first thought illogical to advise plowing under green crops on soils largely made up of organic matter and to suggest fertilizers where there appears to be no lack of plant food. No such positive recommendation is intended, but in the absence of knowledge of the subject such experiments to test this should be undertaken. The beneficial effect of such treatment is well recognized in the Eastern States.

(3) *Soil treatment.*—The chemical treatment of the soil to reduce scab promises but little. Applications of sulphur at the rate of 300 pounds per acre have been used with some degree of success in Delaware and New Jersey and might give good results in California.

SEED TREATMENT FOR SCAB.[a]

The most effective method of disinfecting seed potatoes is by the use of formaldehyde gas liberated by mixing the commercial solution with potassium permanganate. This method is adapted to the disinfection of large quantities of potatoes in a short time. To use it, an air-tight shed should be constructed of sufficient size to hold whatever quantity it may be desired to treat at one time. This may be made of rough lumber, lined with building paper and provided with a tight door. The potatoes may be treated in sacks, but these sacks must be piled so as to allow a free circulation of air all around them. It is suggested that they be piled in tiers, with two 2 by 4 inch scantlings between each layer of sacks. Space should be left in the center of the building for placing the charge of formaldehyde, which should be set off in shallow pans, such as galvanized washtubs. For each 1,000 cubic feet 23 ounces of potassium permanganate and 3 pints of formaldehyde should be allowed. After the potatoes are properly stacked and everything is made ready, the permanganate should be spread in a thin layer on the bottom of the pan, the required quantity of formaldehyde poured in and stirred quickly, and the building vacated. The building should then be kept closed tight for twenty-four hours, when it may be opened and the potatoes taken out.

Formaldehyde is a nonpoisonous but highly irritant fluid which can be purchased in small lots at about 50 cents a pound, in carboy lots at 20 cents, or in barrel lots at about 12 cents. Potassium permanganate is a reddish brown, crystalline substance, purchasable at from 13 to 25 cents a pound.

The precaution should be taken not to pile any potatoes directly over the pans or within 3 feet laterally, as the gas there might be strong enough to injure the potatoes and destroy their germinating power. The formaldehyde works best in a humid atmosphere. It is therefore advised that the floor of the shed be wet down before the treatment is made. The potatoes, however, should not be wet, as the disinfection is more thorough if the surfaces are dry.

Small quantities of potatoes may be disinfected by soaking in a solution of 1 pint of formaldehyde to 30 gallons of water for two hours. Either the gas or the solution treatment may be applied some time previous to planting, provided the potatoes are not exposed to reinfection by being put into receptacles that have previously held scabby potatoes. The treatment should also be made before the potatoes are cut for seed.

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[a] Adapted from Bulletins 141 and 149, Maine Agricultural Experiment Station, by W. J. Morse.

COST OF SEED TREATMENT.

The expense connected with the treatment of seed potatoes by the gas method will vary in different cases according to the amount of labor required in handling and whether a special building has to be erected for the purpose. The cost of labor and of the building will be the principal items. The cost of the materials need not amount to over 1 cent per sack. For example, a shed 12 by 24 feet and 7 feet high contains 2,016 cubic feet and would require 3 pounds of potassium permanganate, costing 60 cents, and 6 pints of formaldehyde, costing $1.20; total, $1.80. Two hundred sacks can easily be treated at once in such a shed. An entire day should be allowed for each treatment.

DECAY OF POTATOES.

Considerable loss is occasionally experienced from the rapid decay of potatoes shortly after harvesting. It is reported that an entire shipment of potatoes will sometimes "go down" in a few days or while en route to market. This trouble is locally known by the expressive term "leak," or "melters."

The affected potatoes turn a dull brown outside; the flesh is buff or brown and very soft. When subjected to pressure a copious amount of clear brown liquid is discharged. There is no bad odor in the early stages.

CAUSE OF THE "LEAK."

This form of decay is due to the invasion of a fungus, *Rhizopus nigricans.* This fungus can enter only through wounds, and experiments in the laboratory have corroborated the testimony of the growers that potatoes injured by careless digging especially are attacked. The fungus spreads rapidly under favorable conditions, growing between the cell walls. Later the cells are separated, and hence the rapid softening of the tissue.

The fungus is propagated by spores produced in large heads or sporangia. It can grow on a great variety of dead organic substances. While it is not usually considered a dangerous parasite, it is known to cause decay in sweet potatoes, apples, and pears, and a related fungus causes a disease of lily bulbs.

REMEDIAL MEASURES FOR THE "LEAK."

Suggestions for the control of this disease may be based on our knowledge of its cause:

(1) Avoid breaking the skin of the potato in handling. Nature has given the potato an effective protection against such fungi in an unbroken epidermis. Rhizopus is a wound parasite, and fork holes and bruises are its principal means of entrance.

(2) Practice sanitary precautions to prevent infection. Keep refuse away from the sorting sheds and docks. The fact that certain locations produce potatoes especially subject to this decay merely shows that these farms are seeded down with the fungus. Rotate crops, as the testimony is that the loss is greatest from old fields.

(3) Avoid piling newly dug potatoes in large piles where they will "sweat." The indications are that infection with the leak fungus takes place most readily at this time. Keep the potatoes dry and well ventilated.

ROTATION PROBLEMS.

The most profitable use of the peat lands, if plant diseases could be left out of consideration, would be to grow continuous crops of potatoes and other vegetables that bring in a large return per acre. The prevalence of wilt and scab necessitates a rotation of crops to maintain sanitary conditions in the soil and raises the question of what crops to alternate with potatoes.

This depends very largely on market conditions and other economic factors. Other vegetables may be substituted, but an overproduction of onions or anything else that has to be sold in near-by markets would quickly result from planting the several thousand acres involved. Celery promises well and experiments with its culture should be made. The asparagus acreage can also be considerably increased.

This circular is written primarily to describe potato diseases. Further work on the subject of profitable crop rotation must be undertaken to solve these problems; hence, only a few suggestions are made here.

It has been pointed out that the simplest and perhaps the best means of reducing the damage to potatoes, especially by the wilt, is the growing in rotation of some other crop not affected by the same diseases. At the present time beans and barley are the two crops most largely grown in rotation with potatoes. There are objections to both of them. The beans are liable to injury by late spring or early fall frosts. Barley for grain is decidedly objectionable on account of the danger of fire, which not only destroys the crop, but frequently destroys the land also, as the peaty soil will burn, and a fire once started in it is very difficult to extinguish.

FORAGE CROPS.[a]

Only a very small amount of experimenting has been carried on as yet to determine what other crops, especially forage crops, can be utilized in rotation. In the light of our present knowledge of these lands the following information can be given, based principally on the investigations of Mr. Roland McKee, of the Office of Forage Crop Investigations.

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[a] Prepared by Prof. C. V. Piper, Agrostologist in charge of Forage Crop Investigations, Bureau of Plant Industry.

SMALL GRAINS FOR HAY.

As before mentioned, barley does well on the peat lands and is quite extensively grown as a grain crop. On account of the danger of fire, however, it is objectionable. Barley cut green for hay is much used in California, and suggests itself principally because it will lessen the danger from fire. It is scarcely probable that the net income from the barley hay would be as great as that from the barley as grain.

Oats have been but little tested on the peat lands, but the evidence indicates that they succeed very well. For hay, oats are distinctly preferable to barley, and little difficulty should be found in marketing large quantities of this hay in San Francisco, as the water freight rates are low.

RYE-GRASS.

Of all the grasses commonly cultivated for hay, Italian rye-grass is by far the best adapted for growing on the peat lands. It will also be particularly suited to rotations from the fact that it is virtually an annual, at least so far as producing paying crops is concerned. Should it be desired to keep the land in grass two years or more, perennial rye-grass should be used. It may be pointed out that the rye-grasses furnish practically all of the commercial hay of England, and in a large measure that of other European countries, where this grass bears the same general reputation that timothy does in this country. It would therefore seem that there would be no difficulty whatever in establishing a permanent market for the hay made from this grass. Rye-grass is also grown extensively in Australia, and considerable seed is imported from that country under the name of Australian rye-grass, which, for the most part at least, consists of Italian rye-grass.

VETCHES.

Several experimental plantings of vetches have indicated that they are well adapted to the California peat lands. There is sufficient time in a year to grow a winter crop of vetch and a summer crop of potatoes, and the time of planting of each could be regulated by the other crop. Vetch hay, however, is primarily of value as a feed for dairy cows and would find little or no sale in city markets. It is therefore not to be recommended except in connection with dairying.

ALFALFA.

Experimental plantings of alfalfa made at Middle River have succeeded well. In the light of these experiments it seems probable that alfalfa will do well on the peat lands where the water is not allowed to come too near the surface. The use of alfalfa, however, would probably necessitate leaving the land in this crop for several years, which might be desirable where the land had become badly infested with potato diseases.

Among the varieties tested at Middle River the Arabian variety was decidedly better than any other. On November 11, 1908, a few weeks after the last cutting of all of the plots, the Arabian alfalfa was 12 inches high, while the ordinary alfalfa had made scarcely any growth. This ability of the Arabian alfalfa to grow during the cool weather of late fall and early spring would be particularly valuable from the standpoint of winter pasturage.

OTHER FORAGE CROPS.

Doubtless many other forage crops, both legumes and grasses, would succeed on the peat lands. Experimental plantings of a large number will be made. The list of those that are known to be successful on these lands is sufficient, however, to meet present needs, and the knowledge of each is so definite that no farmer need hesitate to plant those recommended in these pages.

Approved:
JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *January 9, 1909.*

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